IXS measurements in extreme conditions: A multi-megabar primary pressure scale and the structure of the Earth's core

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Abstract:

Elucidating precise information about the Earth interior is one of the long-standing propositions of the Earth science. However, because we cannot directly go and/or see to the Earth's interior, our knowledge on the Earth's core is based on comparison of laboratory measurements with seismological observations, informed by meteorite composition, and indications of the Earth's core temperature. One of the most interesting topics of such works is the density deficit issue, which is the suggestion that Earth's inner core must contain light elements because the density of the inner core determined from seismological Earth model is lower than the density of pure iron determined from laboratory measurements and/or theoretical work: the density deficit of the inner core has been considered ~4%. However, such conclusion is based on a pressure scale to evaluate laboratory-based measurements. the accurate pressure scale is a prerequisite to high-pressure physics and is critical for relating laboratory-based measurements to actual geological conditions and seismological observations. Also, the pressure scale is one of the most fundamental topics for the condensed-matter physics. However, despite significant effort, there remain large discrepancies in the available scales at the multi-megabar pressures of the Earth's core, and indeed these differences tend to become even larger (approaching a factor of two) as pressures increase. The uncertainty of the pressure scales makes it difficult to estimate the composition of the Earth's core, and in particular, has impact on the possible amount of light elements therein and/or the temperature estimation of the Earth's core. We report here the first primary pressure scale extending to the multi-megabar pressures of Earth's core by measuring longitudinal and transverse acoustic phonon velocities using inelastic x-ray scattering from a rhenium sample in a diamond anvil cell. Our new pressure scale agrees with previous primary scales at lower pressures and also shock compression experiments, but it is lower than previous secondary and theoretical scales at Earth's core pressures: previous scales have overestimated laboratory pressures by at least 20% at 230 GPa. Our new scale suggests the density deficit of the inner core is ~9%, doubling the light-element content of the inner core.